Naval Fuels & Lubricants
Cross Functional Team
Research Report

Navy Coalescence Test on Petroleum F-76 Fuel with FAME Additive at 1%

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EXECUTIVE SUMMARY

The Navy Coalescence Test (NCT) is a fit-for-purpose test which uses a specially manufactured small filter/coalescer cell to simulate the performance of a full scale filter/coalesce system while utilizing a small volume of fuel. This testing is designed to predict the performance of the filter/coalescer systems currently in use in the fleet.

F-76 diesel fuel used onboard USN vessels is procured throughout the world by DLA Energy. Recent DLA Energy sponsored studies have shown that in many countries there is an undesirable concentration of Fatty Acid Methyl-Ester (FAME) present in the F-76. This study was conducted to determine an upper limit to FAME content at which its presence would not affect the coalescence properties of the F-76. This study showed that at 1% (v/v), FAME would not affect the coalescence properties of F-76 following a fuel system flush and a filter change out. This contamination level passed the NCT and is recommended for further fit for purpose testing.

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LIST OF ACRONYMS/ABBREVIATIONS

NCT.. Navy Coalescence Test

PPM. …………………………………………………………………...parts per million

HR76.. ………………………………… Hydroprocessed Renewable F76 grade Diesel Fuel

FAME…..……………………………………………………… . Fatty Acid Methyl-Ester

DEFINITIONS

Turnover.................amount of time it takes to flow the entire volume of fluid in a container, also known as resonance time

Dissolved Water......water that is in solution with the fuel i.e. at or below the saturation point

Free Water ....water in a multi-fluid stream which is above the fluids saturation point

Element ....a separation device which acts upon a fluid stream, these may include filters, coalescers or separators

Coalescence............ the ability to shed water from fuel

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Navy Coalescence Test on Petroleum F-76 Fuel with FAME Additive at 1%

1.0 BACKGROUND

The Navy Coalescence Test (NCT) is a screening tool to determine the impacts of fuel chemistry, fuel, and/or additives on filter-separator performance. The NCT is a scaled down version of a full-scale filter coalescer. The NCT utilizes a miniature version of a full size coalescer and separator assembled in a capsule. The capsule is engineered to have the same flow per unit area as a full size coalescer. The single pass flow rate is 33 mls/min when using diesel fuel, as per the filter coalesce manufacturer's recommendation. The test is comprised of flowing fuel, injecting a known amount of water upstream of the coalescer, and measuring the water concentration in the fuel downstream of the test capsule. The total water content in the fuel is measured at the 1) outlet of the tank (prior to water injection), 2) coalescer inlet (after water injection), and 3) coalescer outlet. By measuring and graphing the results of the water levels at those three points, the effects on coalescence can be determined. When coalescence is not affected, the tank and outlet water levels are close in value and give consistent results. When coalescence is compromised, the inlet and outlet levels of the coalescer are closer and give erratic results. The standard test duration is 80 hours. A flow schematic for the NCT is shown in Figure 1.

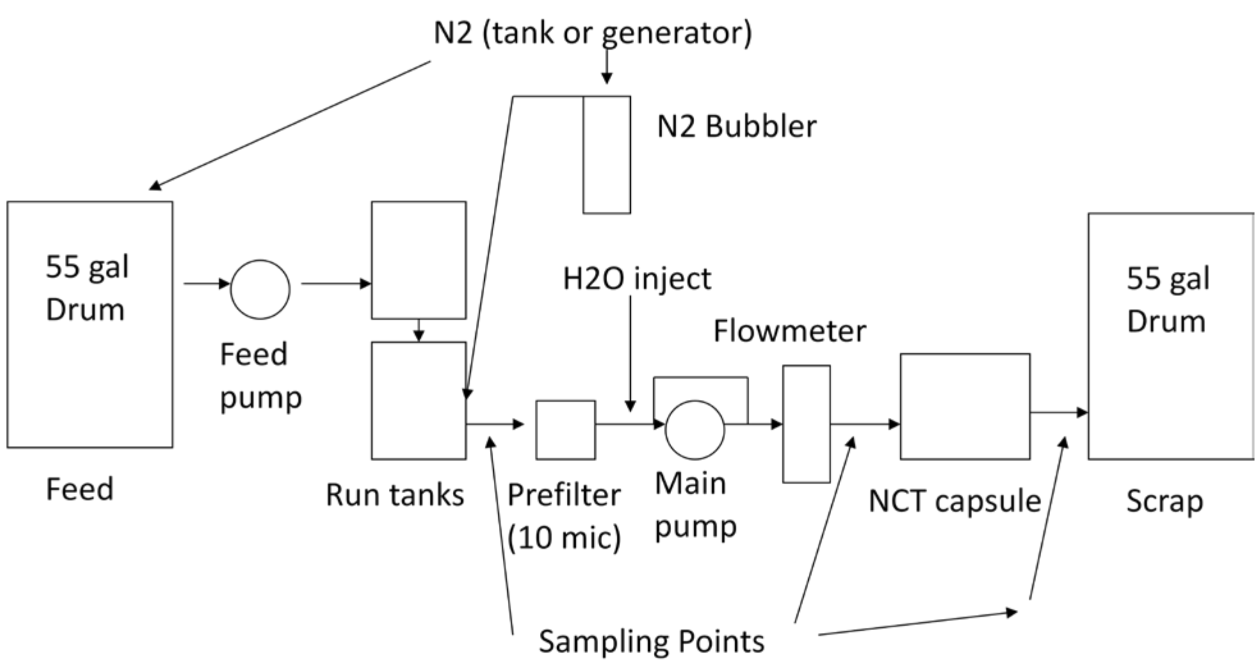

Figure 1: NCT Flow Schematic

Many countries world-wide produce forms of biodiesel which contain varying amounts of FAME as a major constituent. This particular product is very viscous and is known to solubalize normal hydrocarbon deposits from surfaces of fuel systems into the fuel. An upper limit of FAME concentration within F-76 is not currently established and is being partially determined through this test.

2.0 OBJECTIVE

The objective of this test is to determine the water shedding or coalescence properties of the test fuel. Free water levels upstream and downstream of the filter/coalesce test cell will be compared to a saturated level of water in the same fuel. Water is injected upstream of the filter/coalescer. A passing fuel will have downstream measurements which track with the saturated levels instead of the upstream levels. This will indicate satisfactory water separation properties of the test fuel.

3.0 APPROACH

Testing was conducted in accordance with the NCT Standard Work Package (SWP44FL-003). The base fuel was stored in epoxy lined drums, and put through a recirculating filtration stand before it entered the test rig. This is designed to remove any contaminants and establish a contaminant free baseline for the fuel. Each drum was recirculated with a drum pump for 22 turnovers to solubalize any large contaminants in the fuel stream and then recirculated for 122 turnovers through a series of filter/coalescers to remove any contaminants.

Once the fuel was contaminant free, the recirculating stand was put into bypass mode and the test additive was introduced into the fuel. Each drum was recirculated for 7 turnovers using the recirculation pump in order to mix the additive through the entire volume of fuel. The additive added to the fuel was FAME at 1% (v/v).

Once the fuel was additized, it was placed in the test rig. Fuel drums were pressurized with nitrogen to both offset the vacuum produced by the feed pump and inert the system. The rig's feed pump pumps the fuel into a feed tank where it is injected with a feed of nitrogen and de-ionized water. This enabled the fuel to stabilize at a level where it is saturated with dissolved water. A sample of the fuel at this stage is tested using a Karl Fischer coulometric titrator, which reads the total parts per million (ppm) of water in the fuel. This reading is known as the saturated tank level.

The next step injects a constant amount of free water into the fuel stream. This injection rate was set using an explosion-proof electric needle injection pump and a syringe of de-ionized water. The target level of free water injection is 200-300 ppm. This condition was chosen because it represents a significant increase which could be seen in real field conditions. The saturated fuel stream is pumped through the rig using the test pump. This action atomizes the injected water stream with the water saturated fuel stream through the use of recirculation valves. Three samples of this fuel are tested in the Karl Fischer to give an average reading of the total water upstream of the test element housing. These samples are noted as the upstream readings.

The last step is to flow the water and fuel through the filter/coalescer cell test housing. The filter/coalescer and test separator will act on the fuel to separate the water from the fuel using both size occlusion and polarity of materials. Once the fuel has passed through the housing, three samples are tested in the Karl Fischer to give an average reading of the total water at this point in the test rig. These samples are known as the downstream samples.

The test was run for 80 hours of fuel flow through the test element housing at a rate of 33 milliliters per minute. During this time the 7 Karl Fischer measurements above will be measured once an hour. In addition, the total and differential pressure across the test element was measured. If the differential pressure is greater than 15 psi, the filter has been compromised and the test will be reported as a failure. In order to pass the test, the difference in water levels between the saturated tank and the downstream readings must be within 100 ppm of each other. If for four or more hours the difference in average readings is greater than 100 ppm, the test will be reported as a failure. The 100 ppm condition has been chosen because it allows for variations in the fuel sample, as well as random events such as excess water concentration upstream or incomplete saturation due to variations in nitrogen pressure and flow.

4.0 DISCUSSION

This test was conducted to determine the effects of 1% (v/v) FAME on the coalescence properties of the fuel. No other additives were present in the fuel. The first attempt to run this test failed due to a high differential pressure and a very high coalescence difference between the saturated tank and outlet water levels. These phenomena were seen immediately upon start up of the test and lasted for over 20 hours. The test was run the full 80 hours in order to determine the long term effects on the test element; however the element started to burst close to the 80 hour time limit. At this point the injected and downstream values of free water were virtually identical, and the pressure gauges had ceased to function. The pumps needed significantly more air to operate, which indicated that there was a very high differential pressure across the element.

Upon inspection of the element after the test was over, the filter side of the element was completely saturated with dark colored contaminants, which had made their way through into the coalescer, indicating a burst of the element (dP >75 psi). Since the FAME additive is known to solubalize normal hydrocarbon deposits from a fuel system, this was deemed to be the cause of the high pressure event, and a retest was scheduled, which followed the same procedure as indicated in section 3. This retest utilized the same concentration of FAME, base stock of F76 and fuel pre-treatment procedures.

The retest data is reported below. The saturated, upstream and downstream total water concentrations in the fuel stream are graphically represented below in Figure 2. These are graphed by test hour to show the trends in the water levels over the test duration.

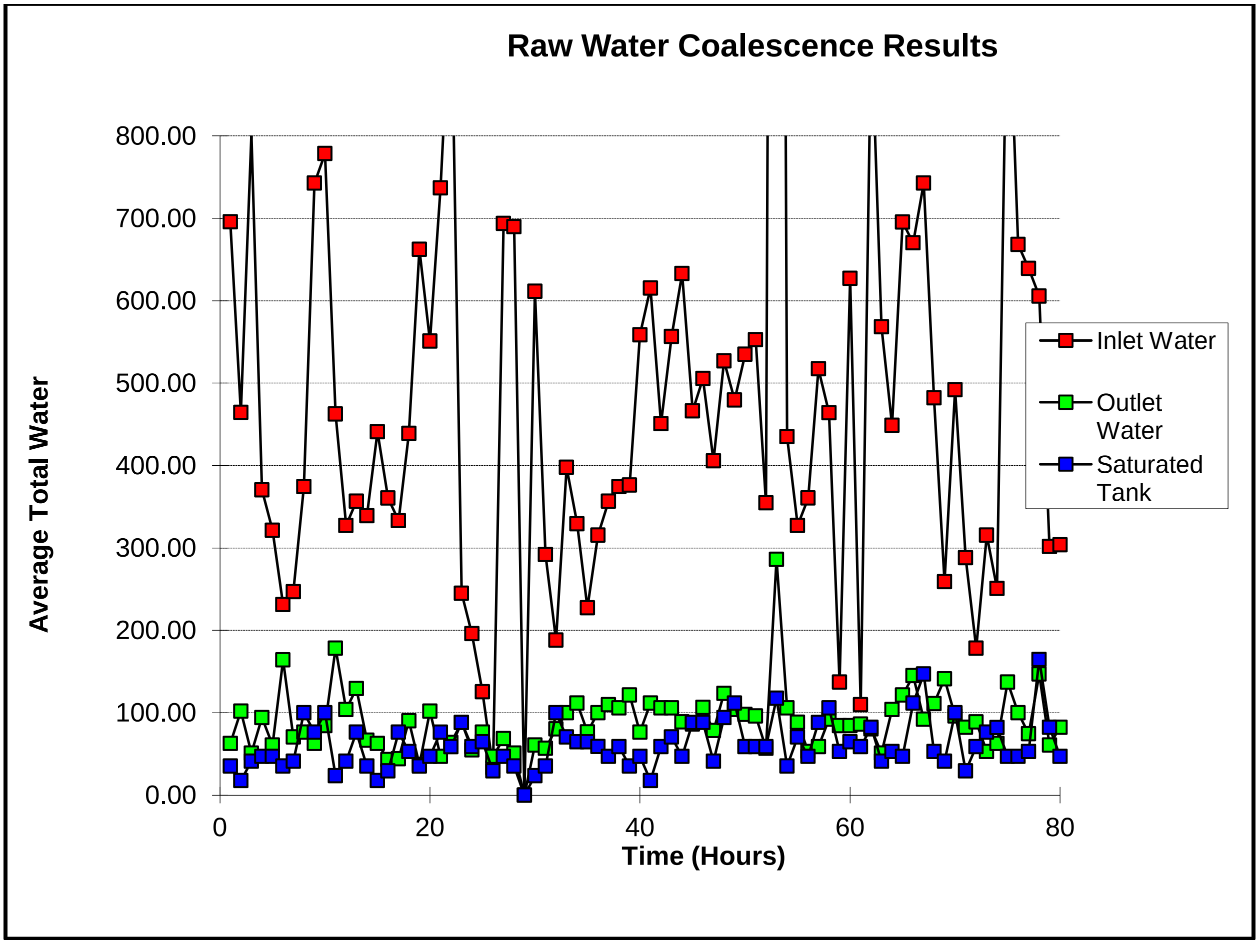

Figure 2: Raw water level data by test hour

As shown in Figure 2, the injected water level varied in concentration, but remained well in excess of the saturated level. The average injected water concentration was 367 ppm and the average tank water saturation level was 59 ppm.

The greatest water separation is seen when comparing the downstream fuel with the saturated fuel in order to see how well the test element removes the injected free water. The difference between the saturated fuel and the downstream fuel is seen in Figure 3 below.

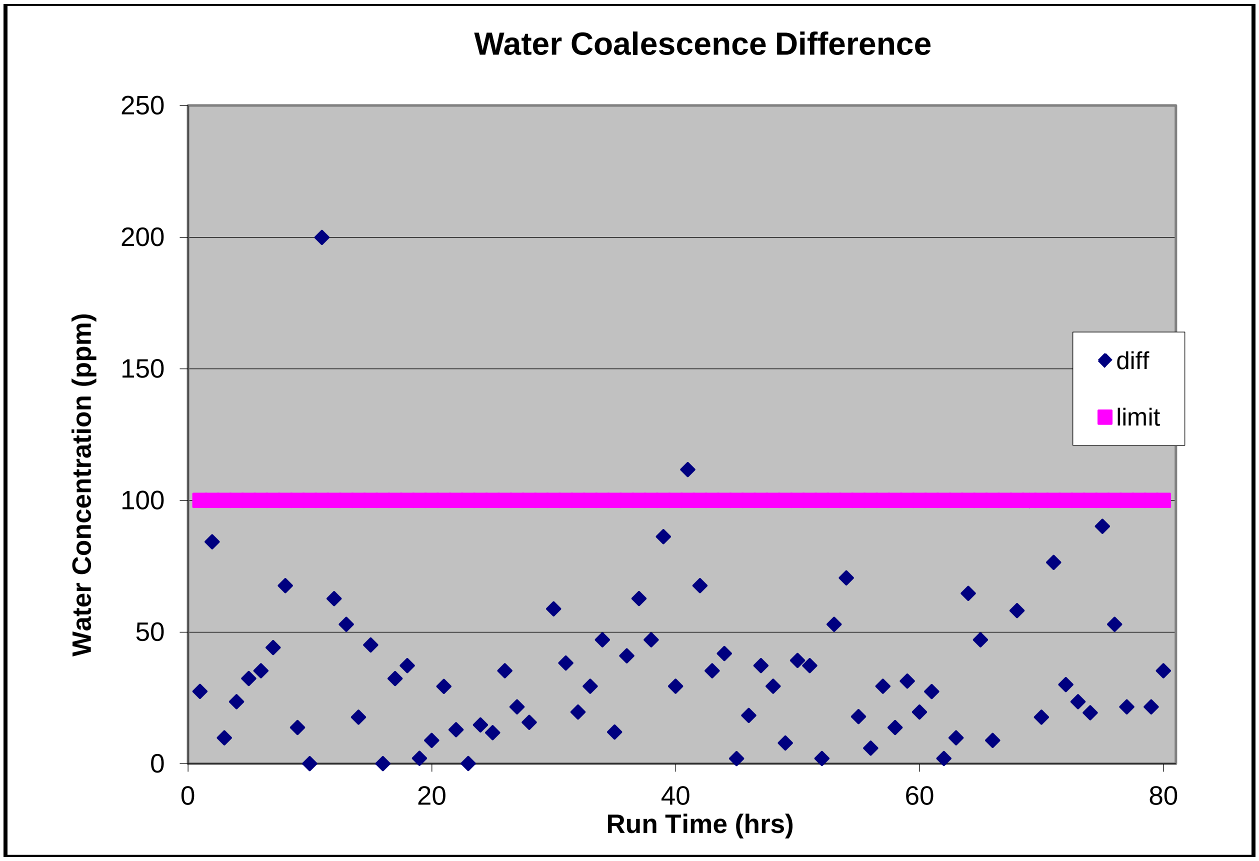

Figure 3. Calculated Water Coalescence Data

Figure 3 shows that all but two points were well under the 100 ppm limit. The average difference between the saturated and downstream water levels was 36 ppm indicating satisfactory coalescence. The pressure gauges on the test rig were non-functioning during this test as discussed above, however the air setting on the system pump indicated that this fuel did not have an adverse affect on system pressure.

5.0 CONCLUSIONS

One filter change out in a fuel system after switching to FAME at 1% or less will allow the fuel system to operate normally. The FAME additive at 1% (v/v) met all the NCT requirements satisfactorily.

6.0 RECOMMENDATIONS

When FAME contamination is suspected in a fuel, the fuel handling / processing system shall be monitored for differential pressure across the filter coalesce elements. Elements shall be changed in accordance with the filter manufacturer's recommendations. At least one filter change out is recommended when recovering from a FAME contamination incident. It is also recommended that F-76 fuel contaminated with 1% (v/v) FAME be further tested for additional impacts.

7.0 REFERENCES

SWP44FL-003 Navy Fuels and Lubricants CFT Navy Coalescence Tester (NCT)

APPENDIX A
Table A-1 Test Data

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	dP (psi)
1	695.67	62.71	35.27	N/A
2	390.95	101.90	17.64	N/A
3	873.02	50.95	41.15	N/A
4	311.58	70.55	47.03	N/A
5	321.38	79.37	47.03	N/A
6	231.24	70.55	35.27	N/A
7	246.85	85.24	41.15	N/A
8	293.95	32.34	99.94	N/A
9	634.92	62.71	76.43	N/A
10	706.35	99.94	99.94	N/A
11	364.49	223.40	23.52	N/A
12	379.19	103.82	41.15	N/A
13	293.95	129.34	76.43	N/A
14	339.02	52.91	35.27	N/A
15	399.77	62.71	17.64	N/A
16	360.51	29.40	29.39	N/A
17	333.07	44.11	76.43	N/A
18	467.37	90.14	52.91	N/A
19	417.40	37.23	35.21	N/A
20	550.95	55.85	47.03	N/A
21	736.82	47.03	76.37	N/A
22	837.75	45.85	58.73	N/A
23	167.55	88.18	88.13	N/A
24	111.70	44.09	58.79	N/A
25	155.79	76.42	64.67	N/A
26	44.09	64.67	29.39	N/A
27	467.37	68.59	47.03	N/A
28	452.68	50.95	35.27	N/A
29	[redacted]	[redacted]	[redacted]	N/A
30	723.11	82.31	23.52	N/A
31	223.40	73.49	35.27	N/A
32	158.73	80.34	99.94	N/A
33	323.35	99.94	70.55	N/A
34	279.25	111.70	64.67	N/A
35	267.49	76.63	64.64	N/A
36	270.43	99.94	58.99	N/A
37	356.65	109.74	47.03	N/A
38	374.29	105.82	58.79	N/A
39	420.34	121.49	35.27	N/A
40	558.49	76.43	47.03	N/A
41	615.26	129.34	17.64	N/A

Table A-1 Test Data (Continued)

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	dP (psi)
42	450.71	126.40	58.79	N/A
43	556.54	105.82	70.55	N/A
44	558.49	88.85	47.03	N/A
45	466.23	86.26	88.18	N/A
46	505.59	106.49	88.18	N/A
47	405.65	78.38	41.15	N/A
48	526.87	123.46	94.06	N/A
49	398.78	103.86	111.70	N/A
50	535.00	97.98	58.79	N/A
51	514.43	96.02	58.79	N/A
52	235.16	56.83	58.79	N/A
53	[redacted]	170.49	117.58	N/A
54	461.49	105.82	35.27	N/A
55	327.26	88.42	70.55	N/A
56	288.07	52.91	47.03	N/A
57	388.01	58.79	88.18	N/A
58	432.10	92.11	105.82	N/A
59	137.17	84.26	52.91	N/A
60	696.65	84.26	64.67	N/A
61	109.74	86.17	58.79	N/A
62	[redacted]	80.34	82.30	N/A
63	568.29	50.95	41.15	N/A
64	532.04	117.58	52.91	N/A
65	737.39	94.06	47.03	N/A
66	670.23	120.52	111.70	N/A
67	505.59	92.10	[redacted]	N/A
68	414.46	111.03	52.91	N/A
69	259.00	141.09	41.15	N/A
70	443.86	117.58	99.94	N/A
71	252.80	105.82	29.39	N/A
72	178.33	88.81	58.79	N/A
73	273.37	52.91	76.43	N/A
74	205.76	62.71	82.03	N/A
75	967.17	137.17	47.03	N/A
76	940.60	99.94	47.03	N/A
77	639.16	74.47	52.91	N/A
78	399.76	73.51	[redacted]	N/A
79	332.16	60.75	82.30	N/A
80	303.74	82.30	47.03	N/A

NOTE: cells which are blacked out represent times at which the test equipment was not operating properly. Since the data trends were normal after the equipment was fixed, the data was deemed suitable for use.

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F-76 diesel fuel used onboard USN vessels is procured throughout the world through DLA contracting. Recent DLA sponsored studies have shown that in many countries there may be an undesirable concentration of Fatty Acid Methyl-Ester (FAME) present in the F-76. This study was conducted to determine an upper limit to FAME content at which its presence would not affect the coalescence properties of the F-76. This study showed that at 1% (v/v), FAME would not affect the coalescence properties of F76 following a fuel system flush and a filter change out. This contamination level passed the NCT and is recommended for further fit for purpose testing.

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